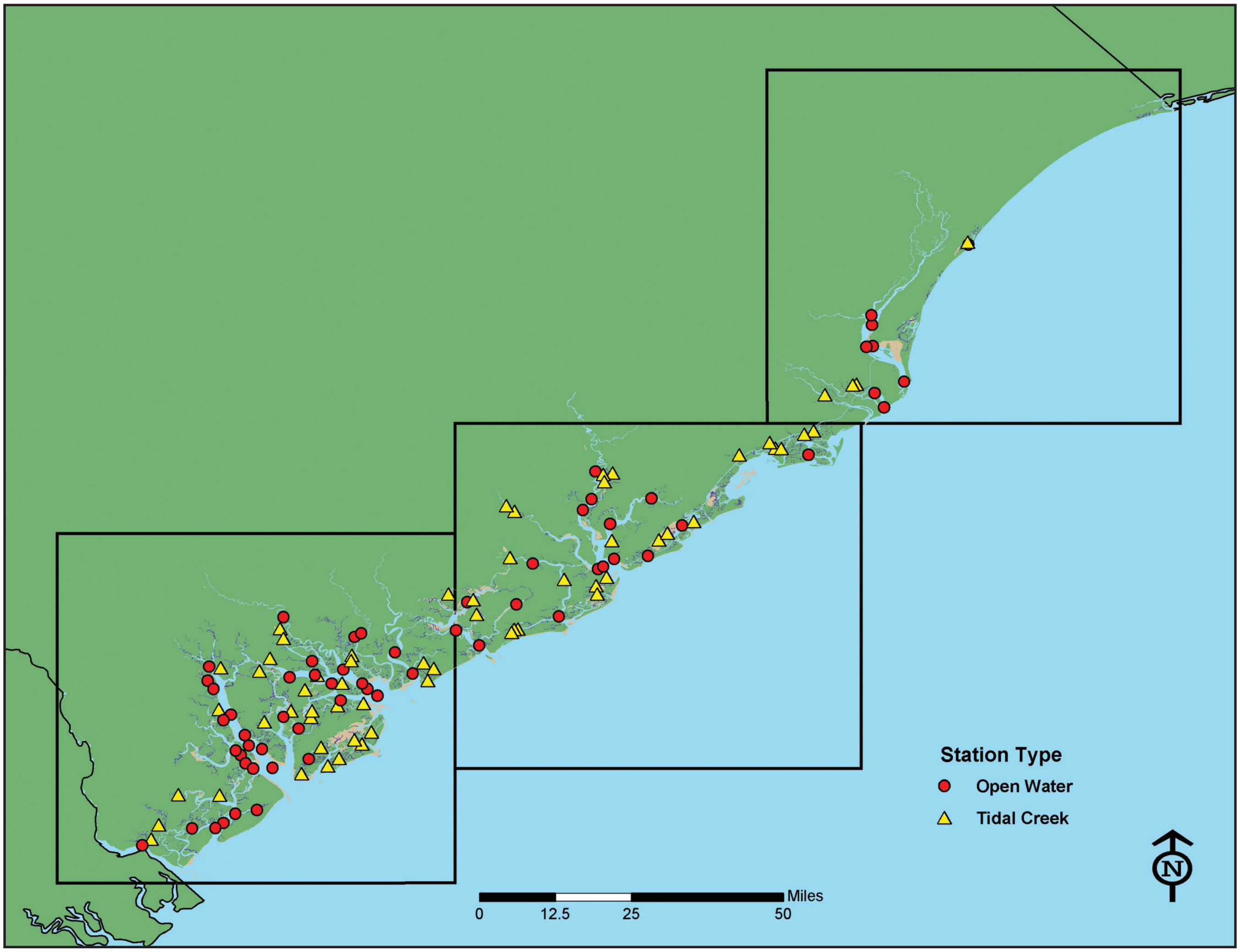

Figure 3.1.1. Distribution of open water and tidal creek stations sampled throughout South Carolina's coastal zone during 2003 - 2004 with northern, central and southern geographic regions outlined.

Average depth of the tidal creek sites was 2.5 m and varied from approximately 0.3 to 6.1 m. Only one site was substantially less than the 1 m minimum criteria due to unusual tidal conditions. Average depths and ranges were comparable to the previous survey periods (Van Dolah *et al*., 2002a, 2004a).

3.2. Water Quality

Although instantaneous measures of basic water quality variables (temperature, salinity, dissolved oxygen, pH) were obtained during the primary visit to each site, the continuous measures of these parameters from the 25-hr instrument deployments provide the most comprehensive information because they include numerous measures during both day and night over two complete tidal cycles. Therefore, these data are used as the primary data set in our analyses of these four water quality parameters. The other measures of water quality (total and dissolved nutrients, BOD_5, TSS, turbidity, TOC, total alkalinity, chlorophyll-*a*, and fecal coliform bacteria) obtained at each site represent instantaneous measures collected during the primary site visit.

State regulations 61-68 and 61-69 have been developed to protect the water quality of the state (SCDHEC, 2004). The water quality standards include numeric and narrative criteria that are used for setting permit limits on discharges to waters of the state, with

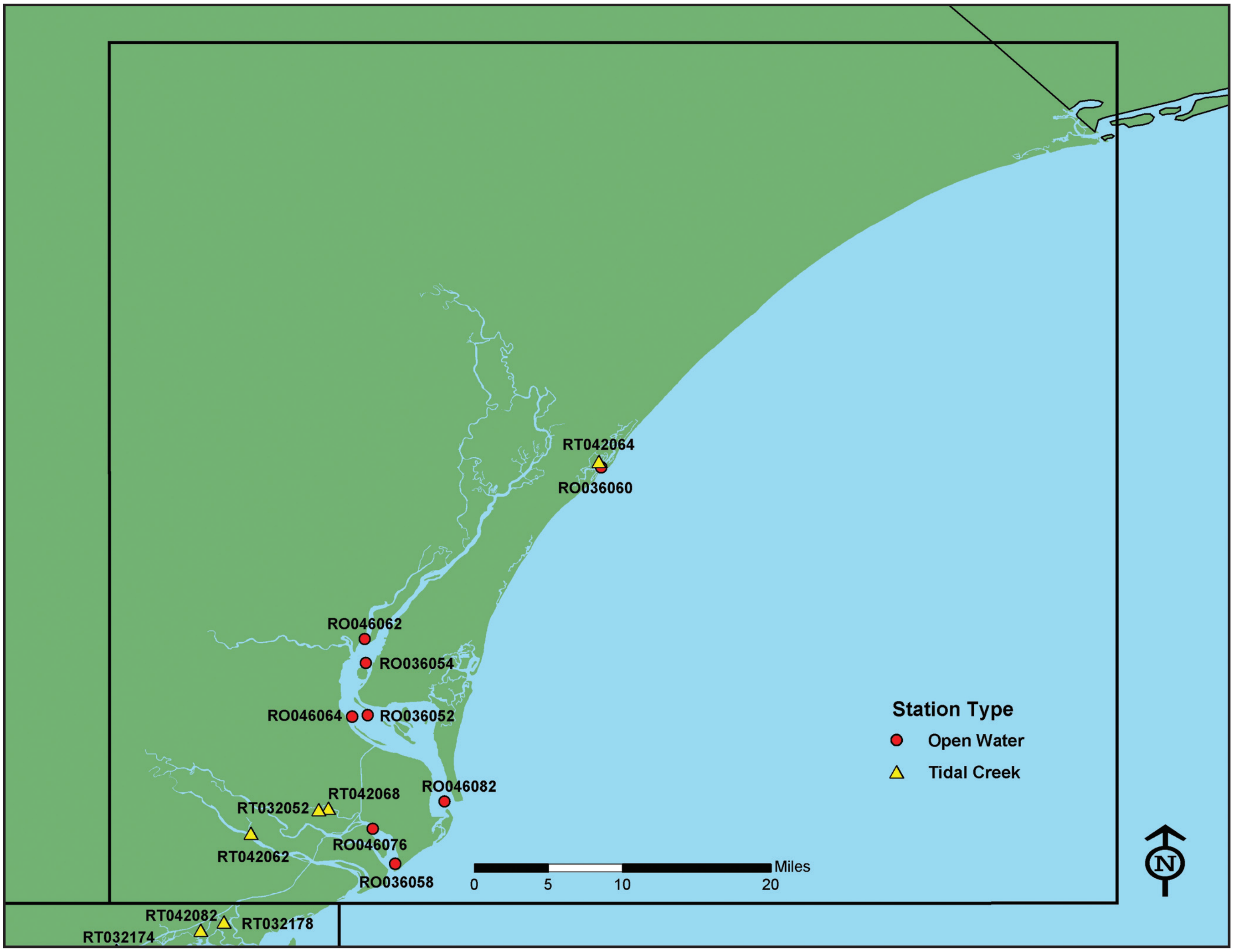

Figure 3.1.2. Distribution of open water and tidal creek stations sampled in the northern portion of the state during 2003 - 2004.

the intent of maintaining and improving surface waters "to a level to provide for the survival and propagation of a balanced indigenous aquatic community of flora and fauna and to provide for recreation in and on the water." Occasional short-term departures from these conditions will not automatically result in adverse effects to the biological community. The standards also recognize that deviations from these criteria may occur solely due to natural conditions and that the aquatic community is adapted to such conditions. In such circumstances, the variations do not represent standards violations, and critical conditions of the natural situation, e.g., low flow, high temperature, minimum dissolved oxygen, etc., are used as the basis of permit limits.

All data collected by SCECAP from field observations and water samples are related to water quality standards for the state's saltwater regions (SCDHEC, 2004) where possible. Because SCECAP samples are limited to a summer index period and generally do not include multiple samples over time, the summertime-only data are not appropriate for use in USEPA 303(d) or 305(b) reporting requirements. Additionally, only four water quality parameters have state water quality standards (dissolved oxygen, pH, turbidity, fecal coliform bacteria). For other parameters measured by SCECAP, values are compared to data compiled for a five-year period (1993-1997) by the SCDHEC Bureau of Water in their routine statewide Fixed Ambient Surface Water Monitoring Network

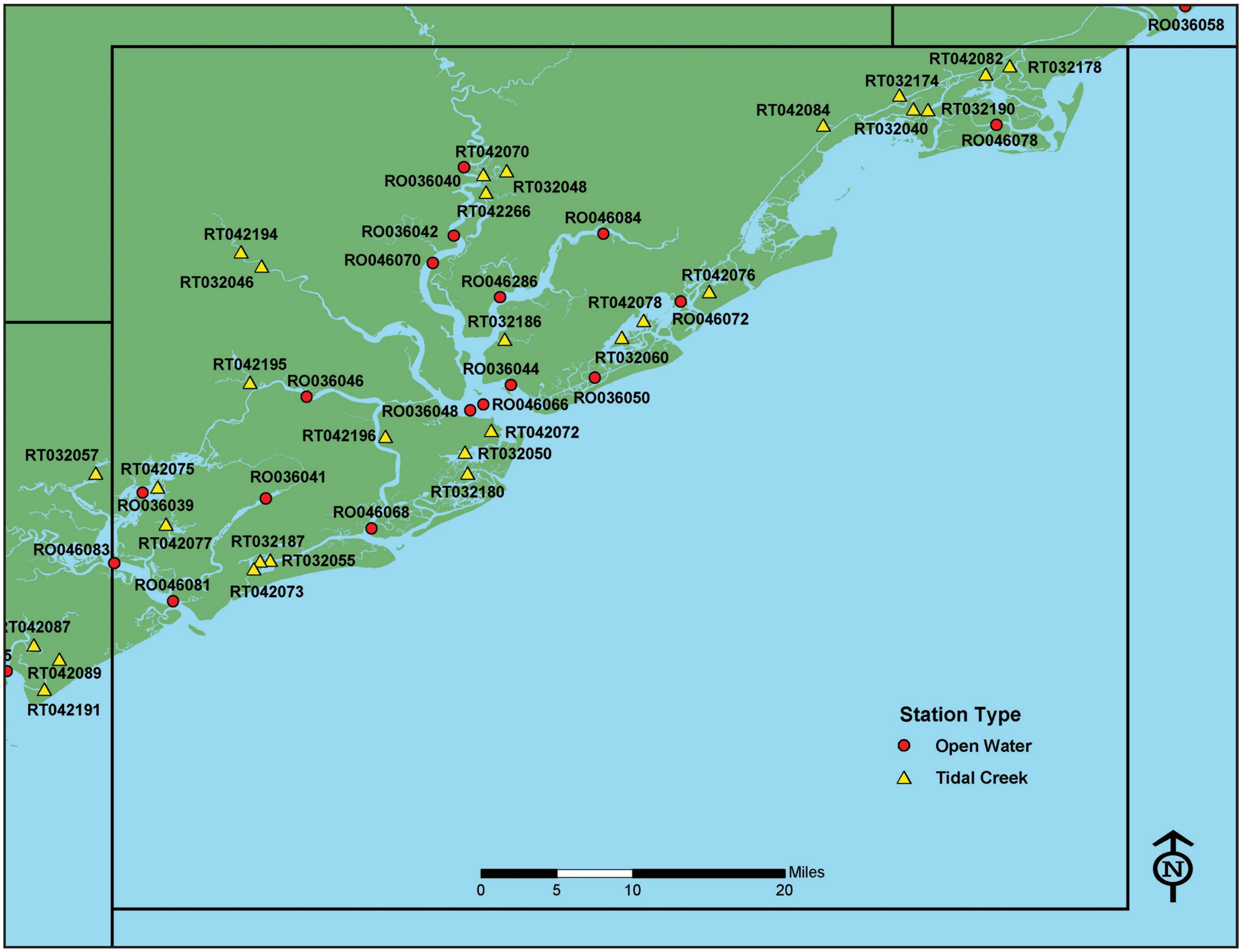

Figure 3.1.3. Distribution of open water and tidal creek stations sampled in the central portion of the state during 2003 – 2004.

(SCDHEC, 1998a). SCECAP criteria consider any value less than the 75th percentile of all 1993-1997 historical values measured (≥ method detection limit) in the state's saltwater habitats as evidence of normal (good) condition. Values exceeding the 75th percentile of the historical data are considered to be elevated (fair), and values exceeding the 90th percentile of all saltwater measures indicate high (poor) concentrations. The SCDHEC historical database on water quality was primarily obtained from larger open water bodies. Therefore, caution should be used in interpreting data obtained from tidal creek sites since high or low values observed for some parameters may represent "normal" conditions. Box 3.2.1 compares the 1993-1997 historical data to both the open water and tidal creek data collected from 1999-2004 by SCECAP. For some water quality variables, such as dissolved nutrients and chlorophyll-*a*, criteria or guidelines published in other reports are used for comparison of conditions (e.g. Bricker *et al.*, 1999; USEPA, 2004) since no appropriate historical data were available for South Carolina.

SCECAP collects many water quality variables that are either required for the NCA Program or for SCDHEC's assessment of state water quality condition for USEPA 303(d) or 305(b) reporting purposes. This technical report summarizes salinity and all water quality parameters that are used for the integrated measure of overall water quality. This report does not summarize temperature, TOC, BOD_5, dissolved nutrients, and alkalinity. Temperature data are primarily collected to relate with other water

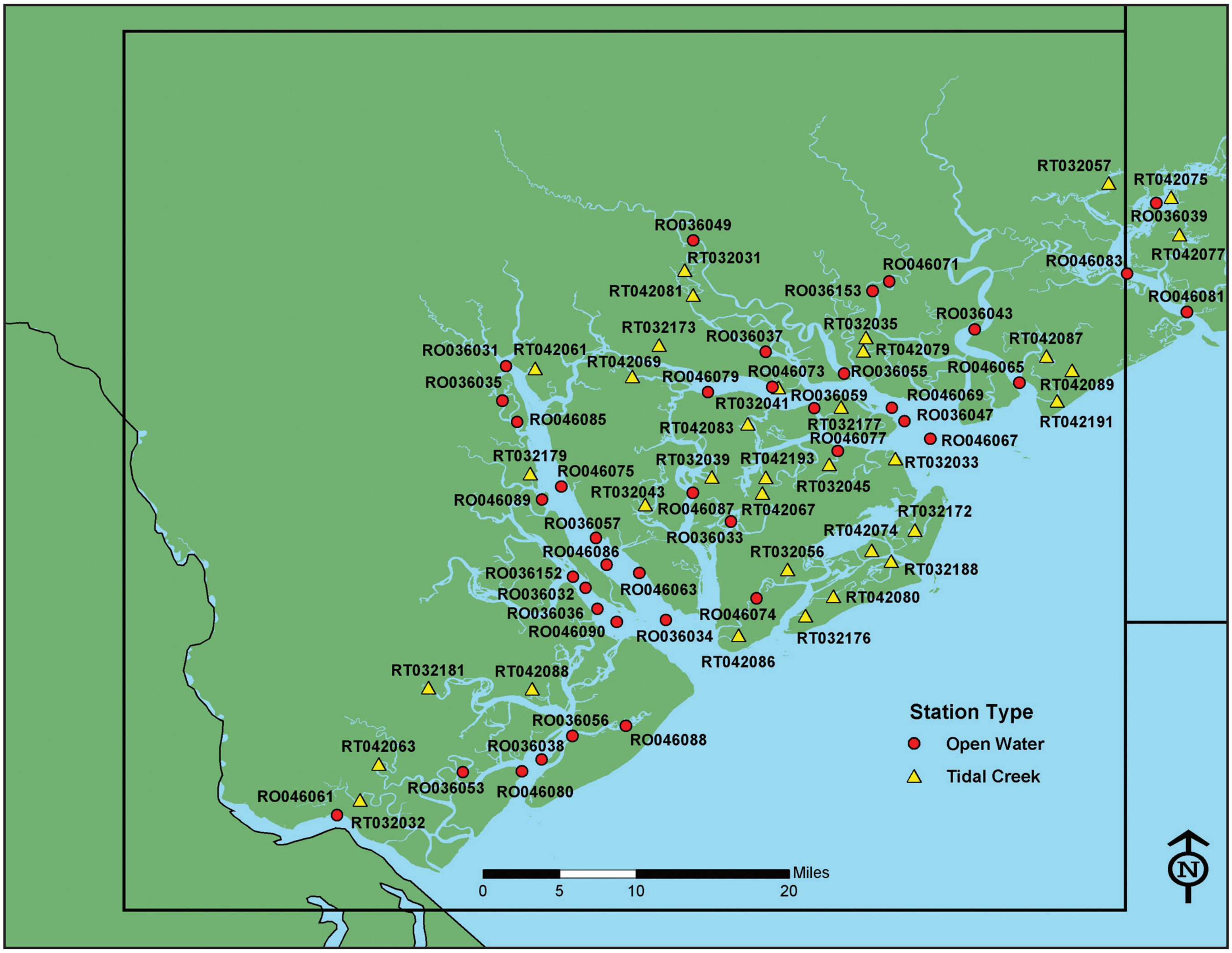

Figure 3.1.4. Distribution of open water and tidal creek stations sampled in the southern portion of the state during 2003 – 2004.

quality variables affected by this parameter. The other excluded parameters have no state standards for estuarine waters. Data on all parameters, reported or not, are provided on the SCECAP web site for those interested in acquiring the data.

Salinity

Salinity influences the distribution and diversity of many invertebrate and fish species and can be stressful to many organisms when large variations occur over short time periods. Mean bottom salinities of all sites sampled during the 2003-2004 survey were 23.5 ppt and 24.2 ppt in the tidal creek and open water habitats, respectively. This difference was not statistically significant ($p = 0.998$), but both means were lower than those observed in the previous two surveys conducted in 1999-2000 and 2001-2002. Additionally, the percentage of the state's estuarine waters that were considered to be oligohaline (≤ 5 ppt) or mesohaline (> 5 to < 18 ppt) was 28% and 29% for tidal creeks and open water habitat, respectively, compared to < 11% for either habitat in the previous two surveys (Figure 3.2.1). This reflects the effects of increased rainfall following a four year record drought. While greater rainfall might be expected to increase the mean range of salinities observed at the sites sampled over a 25-hr period, this was not observed. The average salinity ranges observed were 4.2 ppt among the tidal creek sites and 6.8 ppt among the open water sites, which were similar to the average ranges observed in previous survey periods (data online). However, three tidal creek sites (RT032178, RT042068, RT042084) and four open water sites (RO036043, RO036052, RO036058, RO046081) had salinity ranges ≥ 20 ppt, which may represent stressful conditions to many species. Until additional data are available, no criteria have been established by SCECAP to identify stressful conditions using salinity. The sites having these salinity ranges likely reflect the effects of major rainfall events that occurred just before or during our deployment of the datasondes.

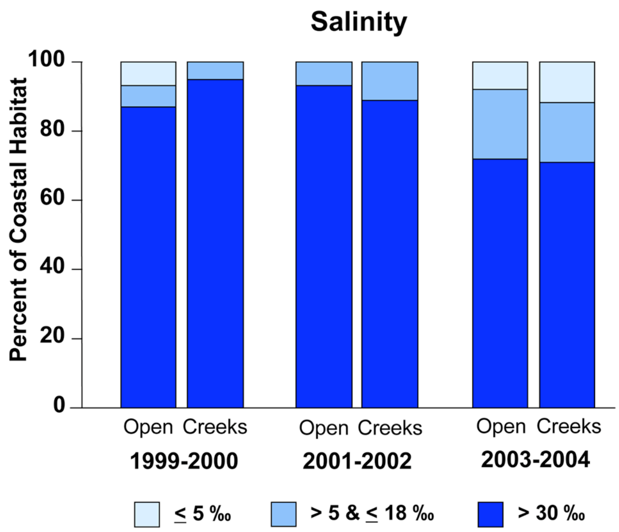

Figure 3.2.1. Comparison of the percent of the state's coastal habitat that represented various salinity ranges during the three survey periods conducted from 1999-2004.

The average difference between surface and bottom salinity measurements taken during the primary station visit was 0.3 ppt in tidal creeks and 0.9 ppt in open water areas. Only one tidal creek site had a difference > 5 ppt, and surface to bottom differences at the majority of creek sites were < 1 ppt (data online). This was also the case for open water stations, with only four stations having > 5 ppt variation in salinity.

Dissolved Oxygen

Low dissolved oxygen (DO) conditions can limit the distribution or survival of most estuarine biota, especially if these conditions persist for extended time periods (see Diaz and Rosenberg, 1995; USEPA, 2001 for reviews). Dissolved oxygen criteria established by the SCDHEC for "Shellfish Harvesting Waters" (SFH) and Class SA saltwaters are a daily average not less than 5.0 mg/L with no values less than 4.0 mg/L (SCDHEC, 2004). Class SB waters should have no values less than 4.0 mg/L. The SCECAP program was designed to sample only during a summer index period when DO levels are expected to be at their lowest. As a result, it was expected that DO measurements collected in this program probably represent short-term worst-case conditions that may not reflect conditions during other seasons or longer time-averaging periods. Although that expected pattern was not reflected in our comparison of summer only versus 12-month measurements of dissolved oxygen (Box 3.2.2), SCDHEC requires year-round monthly measurements for their regulatory purposes. Therefore SCECAP data should be used only to identify coastal habitats where DO levels may be limiting. Based on the state water quality standards, mean or instantaneous DO concentrations > 4 mg/L are considered to be good for summer time periods, values < 4 mg/L and ≥ 3 mg/L are considered to be fair (i.e., contravenes one portion of the state standards), and average or instantaneous measures < 3 mg/L are considered to be poor and potentially stressful to many invertebrate and fish species.

The average bottom DO concentration at the open water stations during the 2003-2004 survey was 5.2 mg/L, with approximately 90% of the state's open water habitat having an average DO > 4.0 mg/L based on the 25-hr instrument deployments (Figure 3.2.2; data online). These conditions were very comparable to DO conditions observed in the previous survey period (Van Dolah *et al*., 2004a). Only two open water sites (representing approximately 3% of the state's open water habitat) had an average DO < 3.0 mg/L (RO036043, RO046076). These sites were in the South Edisto River and the North Santee River, respectively (Appendix 2). The latter site also had an instantaneous bottom DO of 2.3 mg/L, with a surface water DO concentration of 3.1 mg/L.

The average bottom DO concentration observed at tidal creek sites was 4.8 mg/L, with 85% of this habitat having an average DO value > 4.0 mg/L. The average DO value observed among the tidal creek sites was significantly lower than the average DO observed among the open water sites ($p = 0.003$), but this difference is not likely to be biologically meaningful since the average difference was < 0.5 mg/L and both

Box 3.2.1 Comparison of SCECAP Data to Historical SCDHEC Data

Many of the thresholds derived for SCECAP for water quality parameters that don't have state standards were based on a historical database created by SCDHEC (1998a) from 1993-1997. This database predominantly represents conditions found in the larger open water habitats that have been routinely sampled by SCDHEC in their ambient stream monitoring network. Thus, there has been concern that the thresholds may not be as appropriate for tidal creek habitats. Now that six years of data are available through SCECAP, we have computed the 75th and 90th percentile thresholds for a variety of water quality variables monitored through this program. The results suggest that some of the thresholds should be re-considered, but many are very close to the historical thresholds. Those subject to reconsideration include TN, TOC, and turbidity. Even in those cases, there often does not appear to be enough of a difference between the tidal creek and open water thresholds to warrant consideration of separate thresholds for these variables, especially based on the method detection limits (MDL) which provides some indication of likely precision in these measurements. That is not the case for turbidity; however, SCDHEC has already established criteria (25 NTU) for this parameter.

Data Source	TN (mg/L)	TP (mg/L)	Chlorophyll-*a* (µg/L)	TOC (mg/L)	Turbidity (NTU)	BOD_5 (mg/L)
75th Percentiles:						
SCDHEC database (1993-1997)						
All Stations	0.95	0.09	Not measured	11.00	15.00	1.80
SCECAP Database (1999-2004)						
All Stations	0.73	0.10	12.00	8.30	20.50	1.90
Tidal Creek Stations	0.80	0.11	14.00	9.60	26.00	2.20
Open Water Stations	0.68	0.09	10.22	7.88	16.00	1.10
90th Percentiles:						
SCDHEC database (1993-1997)						
All Stations	1.29	0.17	Not Measured	16.00	25.00	2.60
SCECAP Database (1999-2004)						
All Stations	0.98	0.13	17.08	13.00	32.80	2.70
Tidal Creek Stations	0.98	0.14	21.11	14.00	39.80	3.10
Open Water Stations	0.95	0.11	14.52	12.00	24.00	2.40
Method Detection Limits (MDL)	0.10*	0.20		2.00	0.20	2.00

* Based on MDL for TKN, which is the least sensitive components of the TKN+NOx components used to estimate TN

Summary of the 75th and 90th percentile thresholds developed from the SCDHEC historical database currently being used by SCECAP, and the same thresholds based on six years of sampling by the program.

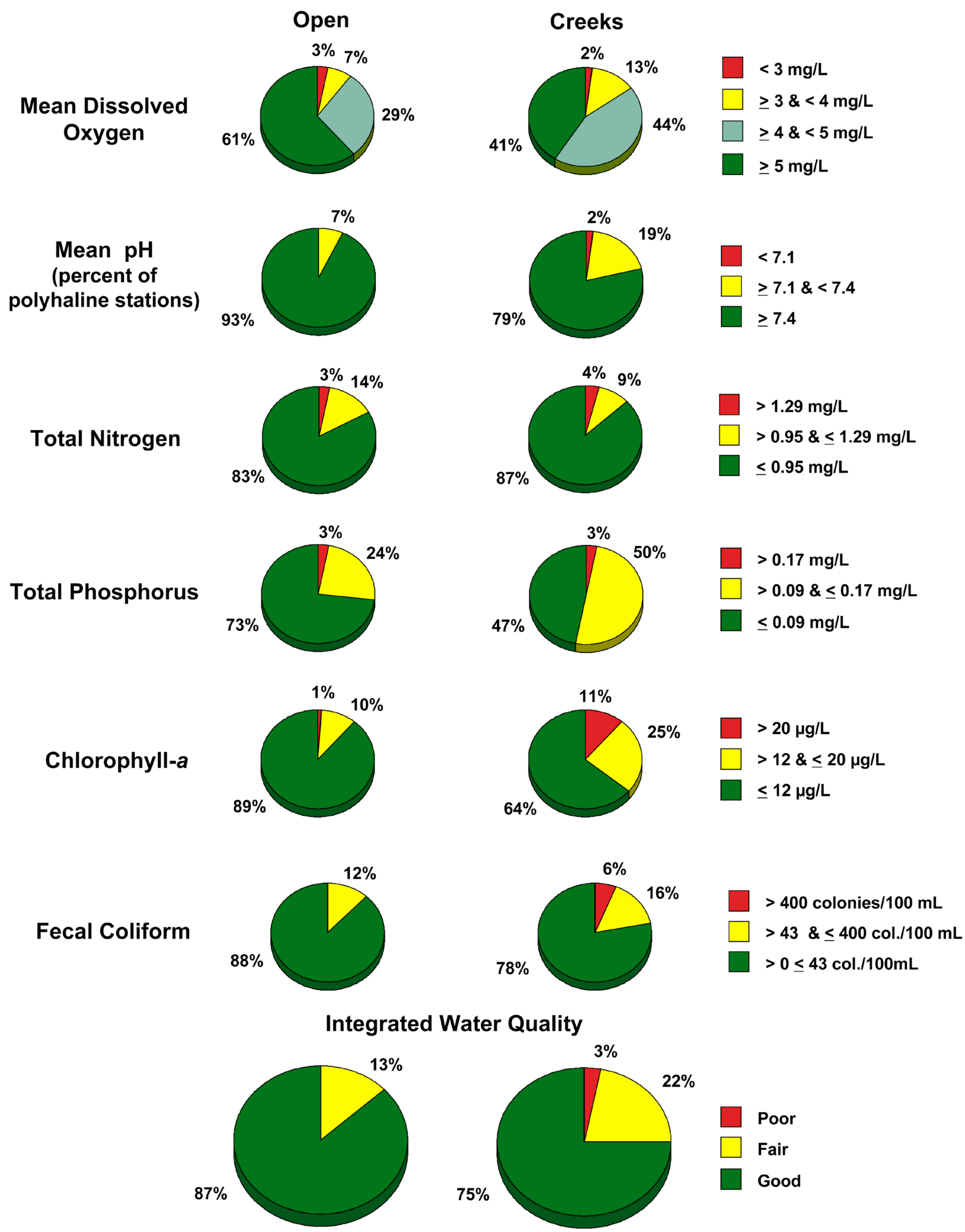

Figure 3.2.2. Comparison of the percent of the state's coastal habitat that represented various water quality conditions for selected water quality parameters and for the integrated water quality index.

averages were > 4.0 mg/L. Approximately 2% of the state's tidal creek habitat had average DO levels < 3.0 mg/L and 13% of this habitat had DO levels between 3.0 and 4.0 mg/L, which is similar to the previous survey period (Van Dolah *et al.*, 2004a) Tidal creek sites often had a greater range in DO concentrations than the open water sites (data online).

Although numeric state DO standards apply to all waters, the SCECAP data continue to suggest that lower DO concentrations in tidal creeks may be normal during the summer months compared to larger water bodies. When making regulatory decisions in such situations, the practice of considering natural background conditions seems appropriate. Even so, creek sites with mean DO levels < 3.0 mg/L may not fully support biological assemblages, especially during periods when DO levels are less than 2.0 mg/L (hypoxic conditions). Hypoxic conditions are known to be limiting to many estuarine and marine biota (Gibson *et al*., 2000).

As noted in the previous two survey periods (Van Dolah *et al*., 2002a, 2004a), the instantaneous measures of bottom DO were, on average, lower than the mean DO values obtained from the 25-hr deployment of water quality datasondes among both the open water (0.7 mg/L difference) and tidal creek sites (1.1 mg/L difference, data online). In contrast to the previous surveys, these differences were statistically significant ($p < 0.002$) during the current survey. The instantaneous bottom DO measure at each site was only weakly correlated to the average bottom DO obtained from the 25-hr instrument deployment ($r^2 = 0.22$), which was also the case in the previous surveys. While instantaneous measures of DO and other water quality parameters are the only feasible approach for SCDHEC to use for the year-round assessment of coastal water quality, mean DO conditions are best measured over a longer period that includes both day and night measures during all tidal stages.

Finally, it should be noted that SCDHEC uses surface water quality measures for regulatory and reporting purposes. The mean differences between surface and bottom readings during the primary site visit was only 0.2 mg/L for both habitat types and only two open water sites had a difference in DO readings of more than 1.0 mg/L (data online). Thus, the surface readings should be reasonably protective of bottom water habitats for South Carolina waters.

pH

Measures of pH provide another indicator of water quality in estuarine habitats that has often been ignored by other sampling programs at the state or national level. Measures of pH are based on a logarithmic scale, so even small changes in the value can result in significant stress to estuarine organisms (Bamber, 1987, 1990; Ringwood and Keppler, 2002). Unusually low or high pH values may indicate the presence of pollutants (e.g. release of acids or caustic materials) or high concentrations of carbon dioxide (Gibson *et al.*, 2000). Because salinity and alkalinity affect the pH of estuarine waters, SCDHEC has established water quality standards that account for these effects. The pH in Class SA and SB tidal saltwater areas should not vary more than one-half of a pH unit above or below effluent-free waters in the same geologic area having a similar salinity, alkalinity and temperature, and values should never be lower than 6.5 or higher than 8.5. Shellfish Harvesting waters (SFH) shouldn't deviate more than 0.3 units from effluent-free waters. Based on these criteria, pH criteria were established for SCECAP assessments using data collected from pristine environments sampled in 1999-2000 (e.g. Cape Romain National Wildlife Refuge, ACE Basin and North Inlet-Winyah National Estuarine Research Reserves, SFH class saltwaters) to identify pH levels that were considered to represent good, fair, and poor conditions for polyhaline waters (> 18 ppt; Van Dolah *et al*., 2002a). For polyhaline waters, pH levels $\geq$ 7.4 are considered to be good. Values below 7.4 and above 7.1 pH units are considered to be fair since they represent the lower 10th percentile of all pH records observed for polyhaline waters during the 1999-2000 survey. Values below 7.1 pH units are below the 0.5 pH unit variation allowed for effluent-free waters and are considered to be poor pH conditions. Criteria are still not established for lower salinity waters since the extreme drought conditions experienced from 1999-2002 limited the number of sites with salinities < 18 ppt. The return of normal rainfall conditions should allow us to develop criteria for oligohaline and mesohaline waters following the 2005-2006 survey now in progress.

The overall average pH observed in 2003-2004 based on the 25-hr measures was 7.3 in tidal creek habitats and 7.6 in polyhaline open water habitats, with approximately 79% of the state's polyhaline tidal creek habitat and 93% of the open water habitat having good pH conditions (Figure 3.2.2, data online). Criteria for lower salinity waters are still not available using the approach developed by SCECAP. As with the previous surveys, the mean instantaneous pH of surface waters within each habitat was within 0.1 pH unit of the mean bottom pH based on the continuous measurements. All mean values were also very similar to the averages observed in the 1999-2000 and 2001-2002 surveys (Van Dolah *et al*., 2002a, 2004a). Mean pH values were significantly lower in the tidal creek habitats compared to the open water habitats ($p < 0.001$) with a higher percentage of the state's polyhaline creek habitat having pH values considered to be only fair or poor compared to polyhaline open water habitat (Figure 3.2.2). Similar trends were noted in the previous two surveys (Van Dolah *et al*., 2002a, 2004a). Additionally, five tidal creek stations (RT032031, RT032046, RT032052, RT042062, RT042084) and two open water stations (RO036049, RO036054) had 25-hr pH means below the minimum (6.5) criteria established by SCDHEC. The locations of sites that had moderately low to very low pH values are provided in Appendix 2.

Nutrients

Nutrient concentrations in estuarine waters can become high due to runoff from upland urban and suburban developments, agricultural fields adjacent to estuarine habitats, riverine input of nutrient-rich waters from inland areas, and atmospheric deposition. High nutrient levels can lead to eutrophication of estuarine waters resulting in excessive algal blooms (including harmful algal species), decreased dissolved oxygen, and other undesirable effects that adversely affect estuarine biota (Bricker *et al*., 1999). Currently, there are no state standards in South Carolina estuarine waters for the various forms of nitrogen (except ammonia) and phosphorus. Therefore, the SCECAP data are compared to SCDHEC's historical database (SCDHEC, 1998a) to identify waters showing evidence of elevated nutrients. Values below the 75^{th} percentile of the historical database are considered to be good, values above the 75^{th} percentile and below the 90^{th} percentile are considered to be moderately elevated (fair), and values above the 90^{th} percentile are considered to be high (poor).

Nitrogen:

Total nitrogen (TN), as measured by the SCDHEC laboratory, is best represented by the sum of nitrate-nitrite and total Kjeldahl nitrogen (TKN). Based on historical SCDHEC (1998a) data, TN values ≤ 0.95 mg/L are considered to be good. Values > 0.95 mg/L and < 1.29 mg/L are considered to be fair since they are above the upper 75^{th} percentile of the historical records and below the 90^{th} percentile of those records. Values above 1.29 mg/L are considered to be poor since they represent the upper 90^{th} percentile of the historical records.

In 2003-2004, the mean concentration of TN was 0.67 mg/L among the tidal creek sites and 0.66 mg/L among the open water sites. There was no significant difference between mean TN values observed in the tidal creek versus open water habitat ($p = 0.596$), which was also the case in the 2001-2002 survey, but not in the 1999-2000 survey when tidal creeks had a significantly higher nitrogen concentration compared to open water habitat. Approximately 93% of the nitrogen was in the form of TKN (organic fraction plus ammonia) when all stations were considered collectively. Mean nitrate-nitrite values in the creeks and open water sites were only 0.03 and 0.05 mg/L, respectively, which was similar to the values observed in the previous surveys.

Using the sum of the detectable values for nitrate-nitrite and TKN as an indication of TN enrichment, about 83% of open water habitat and 87% of tidal creek habitat had nitrogen levels indicative of good conditions. Fourteen percent of the state's open water habitat and 9% of the state's creek habitat had moderately elevated TN concentrations, considered to be fair (Figure 3.2.2, data online). Additionally, 3% of the open water habitat and 4% of the creek habitat had nutrient values considered to be poor. The percentage of the state's estuarine habitat with fair or poor TN concentrations was higher than observed in either the 1999-2000 or 2001-2002 surveys (Figure 3.2.3). This probably reflects the effects of increased runoff from upland habitat as compared to the drought period of the previous two surveys. Sites with very high TN concentrations were located in a creek in Clark Sound

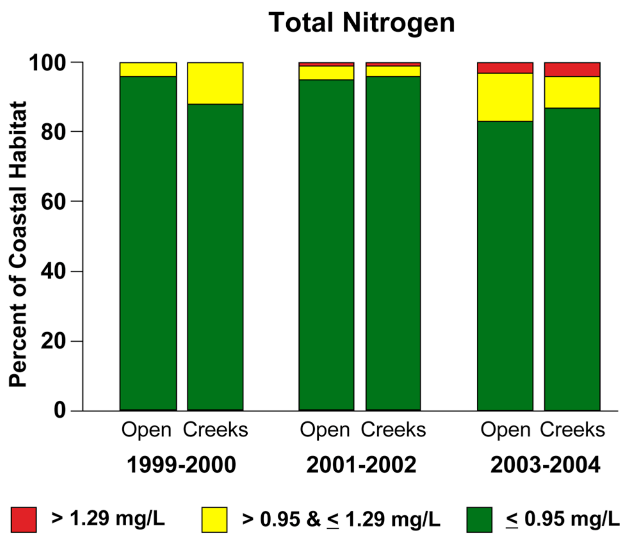

Figure 3.2.3. The percent of the state's coastal habitat representing various TN that are considered to be normal (green), fair (yellow), or poor (red) values relative to SCDHEC historical data during the three survey periods conducted to date.

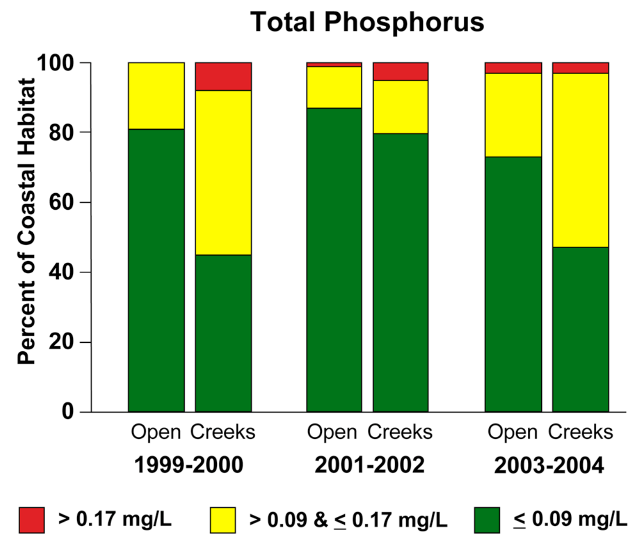

Figure 3.2.4. The percent of the state's coastal habitat representing various TP concentrations that are considered to be normal (green), fair (yellow), or poor (red) values relative to SCDHEC historical data during the three survey periods conducted to date.

off of Charleston Harbor (RT032050), the Intracoastal Waterway at Goat Island (RO036050), the Ashepoo River (RO036152), Winyah Bay at the mouth of the PeeDee River (RO046062), near Belle Isle Gardens (RO046064) and in the Ashley River (RT042192) near Middleton Gardens (Appendix 2). None of these sites had elevated concentrations of chlorophyll-*a*, another measure of possible estuarine eutrophication (see Chlorophyll-*a* section).

Phosphorus:

Based on SCDHEC historical survey data (SCDHEC, 1998a), total phosphorus (TP) levels ≤ 0.09 mg/L are considered to be good. TP concentrations > 0.09 and ≤ 0.17 mg/L represent concentrations above the 75th percentile and below the 90th percentile of historical records and are considered to be fair and. Concentrations > 0.17 mg/L are considered to be poor since they represent the upper 90th percentile of the historical observations. The mean TP measured by SCDHEC in 2003-2004 was 0.10 mg/L at the creek sites and 0.07 mg/L at the open water sites (data online). In contrast to the previous surveys in 2001-2002, this difference was statistically significant ($p = 0.002$) and comparable to the means observed during our first survey period in 1999-2000. Only 73% of open water habitat and 47% of tidal creek habitat had TP concentration considered to reflect good conditions. However, only 3% of the state's creek and open water habitat had TP concentrations that exceeded the 90th percentile (the threshold for poor conditions) of the SCDHEC historical database (SCDHEC, 1998a; Figure 3.2.2). The percentage of the state's coastal creek and open water habitat that was considered fair or poor with respect to TP concentrations was substantially greater than observed in 2001-2002, but not very different from the 1999-2000 survey (Figure 3.2.4). The relationships between changes in estuarine TP concentrations, regional rainfall patterns and

The upper Ashley River is home to several of South Carolina's historic plantation houses and managed gardens. Photo credit: Susan Tobias anthropogenic inputs remains unclear and deserves further attention.

Tidal creek sites with very high TP concentrations were located in the upper Ashley River near Runnymede Plantation and Middleton Gardens (RT032046, RT041294; Appendix 2). This latter creek also had very high total nitrogen concentrations. Open water sites with very high TP concentrations were near the mouth of the Pee Dee River and in Winyah Bay near Belle Isle Gardens (RO046062, RO046064; Appendix 2).

Chlorophyll-a

Our measure of phytoplankton biomass in the water column is based on chlorophyll-*a* concentrations. Other phytoplankton pigments were also examined using HPLC analyses to determine phytoplankton composition (see Section 3.4). High chlorophyll-*a* concentrations provide an indication of possible estuarine eutrophication since phytoplankton respond rapidly to enriched nutrient concentrations and can form blooms that result in poor water quality (e.g., low DO, large DO variations) and the presence of harmful algal species. For SCECAP, chlorophyll-*a* concentrations $\leq$ 12 µg/L are considered to be good. Chlorophyll-*a* values > 12 µg/L represent the upper 75th percentile of all chlorophyll-*a* concentrations measured by the SCECAP program and are considered to be only fair. Chlorophyll-*a* concentrations above 20 µg/L are considered to be high or poor based on criteria or guidelines published by Bricker *et al.* (1999) and the USEPA (2004).

The mean chlorophyll-*a* concentration was 11.8 µg/L in creek habitats and 7.6 µg/L at the open water sites. This difference was statistically significant ($p < 0.001$), but both means represent relatively low concentrations based on the SCECAP database (i.e., < 75th percentile). Using SCECAP criteria, 11% of the state's tidal creek and 1% of the open water habitat had chlorophyll-*a* concentrations considered to be poor (Figure 3.2.2). The slightly higher chlorophyll concentrations in tidal creeks may be reflective of the higher nutrient concentrations observed in the creeks. It may also reflect possible re-suspension of benthic algae from the creek bottoms and nearby marsh surfaces.

An analysis of the relationships between total nutrient concentrations and chlorophyll-*a* concentrations using all six years of available data showed very little correlation between TN and chlorophyll-*a* concentrations (r^2 =0.0185) or between TP and chlorophyll-*a* concentrations (r^2 = 0.0143) (Figure 3.2.5). This is similar to the findings obtained by Van Dolah *et al.* (2004a) in previous survey periods of estuarine habitats. Similarly, Brock (2005) could find no relationships between phosphorus and chlorophyll-a concentrations in brackish stormwater ponds in SC. Therefore, the poor relationships between TN and TP and chlorophyll-a suggest a need to reconsider the utility of using nutrient concentrations as indicators of eutrophication. The lack of a good correlation with either nutrient parameter is likely due to a combination of nutrient-algae dynamics and the high tidal amplitude present in South Carolina estuaries, the latter of which reduces formation of blooms that might otherwise occur in more stagnant waters or in estuaries that have much lower tidal flow.

Fecal Coliform Bacteria

Fecal coliform bacteria are sampled as a measure of potential health hazard in estuarine waters related to primary contact recreation such as swimming and shellfish harvesting. State fecal coliform standards to protect primary contact recreation requires a geometric mean count that does not exceed 200 colonies/100 mL based on five consecutive samples in a 30-day period and no more than 10% of the samples can exceed 400 colonies/100 mL. To protect for shellfish consumption, the geometric mean shall not exceed 14 colonies/100 mL and no more than 10% of the samples can exceed 43 colonies/100 mL (SCDHEC, 2004). Since only a single fecal coliform count is collected at each site during SCECAP surveys, compliance with the standards cannot be strictly determined, but the data can provide some indication of whether the water body is likely to meet standards. For SCECAP, we consider any sample with $\leq$ 43 colonies/100 mL to be good. Samples with > 43 colonies/100 mL and < 400 colonies/100 mL represent fair conditions (i.e., potentially not supporting shellfish harvesting) and any sample with > 400 colonies/100 mL represents poor conditions (i.e., potentially not supporting primary contact recreation).

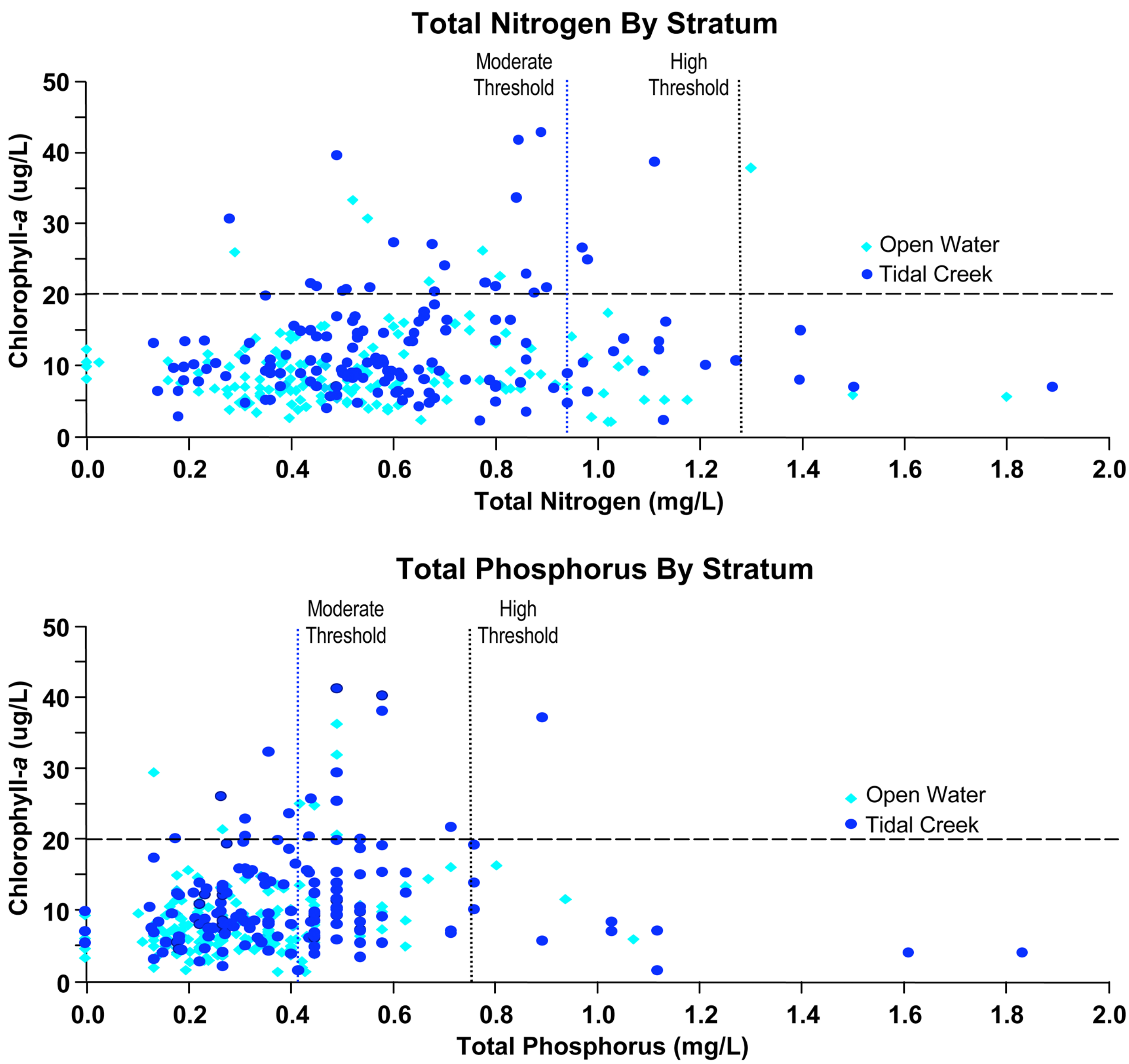

Figure 3.2.5. Summary of chlorophyll-a versus total nitrogen (TN) and total phosphorus (TP) measures collected at SCECAP sites sampled from 1999-2004. The vertical dotted lines represent the 75th and 90th percentile values based on a historical database (SCDHEC, 1998a). The horizontal dotted line represents the concentration of chlorophyll-a that is considered to be high by Bricker et al. (1999) and the USEPA (2004).

The arithmetic mean of fecal coliform measurements obtained during the 2003-2004 statewide assessments were 21.0 colonies/100 mL in open water and 80.2 colonies/100 mL in the creek sites (data online). This difference was statistically significant ($p < 0.05$) and more than double the mean fecal coliform concentrations observed in the 2001- 2002 survey (Van Dolah et al., 2004a). The relatively high mean for tidal creeks was largely due to the presence of very high fecal concentrations (range of 500-900 colonies/100 mL) at four tidal creek sites (R032046, RT032174, RT042062, and RT042194). Two of those sites were located in the upper Ashley River, which also had high nutrient concentrations. None of the open water stations had fecal coliform concentrations > 130 colonies/100 mL. Using the SCECAP criteria, approximately, 88% of the state's open water habitat also had good fecal coliform concentrations, 12% had moderately high fecal coliform concentrations and no sites had coliform colony counts > 400 colonies/mL (Figure 3.2.2). Approximately 78% of the state's creek

Box 3.2.2 Comparison of Sampling Protocols Used for SCECAP and Other SCDHEC Monitoring and Reporting Activities

A subset of sites sampled each year for SCECAP (Core Sites) is also sampled monthly by SCDHEC for a suite of water quality parameters used in Clean Water Act 305(b) reporting activities. This provides an opportunity to compare how the one-time SCECAP sampling approach compares with routine water quality sampling conducted by SCDHEC, using both the water quality criteria established for SCECAP and other water quality criteria used by SCDHEC for their 305(b) assessment.

12-Month Versus One-Time Assessments

Because the SCECAP Integrated Water Quality Score (IWQS) was developed based on a one-time visit at each site, it was necessary to devise a comparative approach for sample observations collected throughout the year at the same stations. To calculate a comparable IWQS for the monthly data, the general assessment approach used by SCDHEC for Clean Water Act reporting activities (SCDHEC, 2006) was adapted for application using SCECAP IWQS parameters and thresholds. This required scoring the monthly data obtained for the six water quality parameters as shown in Table A. The IWQS then was calculated following the single sample procedure (Van Dolah *et al*. 2004a).

Table A: Criteria used to code each parameter in order to translate SCDHEC 305(b) reporting methodology into the 12-month IWQS.

	SCDHEC 305(b) Parameter Codes As:		
Parameter	**Good**	**Fair**	**Poor**
Dissolved Oxygen pH Fecal Coliform	< 2 samples exceeded SCECAP fair threshold	≥ 2 samples exceeded SCECAP fair threshold	≥ 2 sample exceeded SCECAP fair threshold and ≥ 1 was poor
Total Nitrogen Total Phosphorus Chlorophyll-*a*	< 3 samples exceeded SCECAP fair threshold	≥ 3 samples exceeded SCECAP fair threshold	≥ 3 samples exceeded SCECAP fair threshold and ≥ 1 was poor

The one-time and 12-month assessments using the SCECAP IWQS thresholds produced very different conclusions (Figure A). Compared with the one-time assessment, the 12-month assessment indicates a considerably lower percentage of estuarine habitat is in good condition and a higher percentage is in fair or poor condition. Total phosphorus had the greatest influence on the differences in both the tidal creek and open water habitats, primarily based on the large number of individual sites classified as poor in the 12-month assessment as compared to the one-time assessment (Table B). In tidal creeks, chlorophyll-*a* and, to a lesser extent, fecal coliform bacteria also contributed to the overall difference in the classification of individual sites. Fecal coliform bacteria may also account for some of the differences in the open water habitat results.

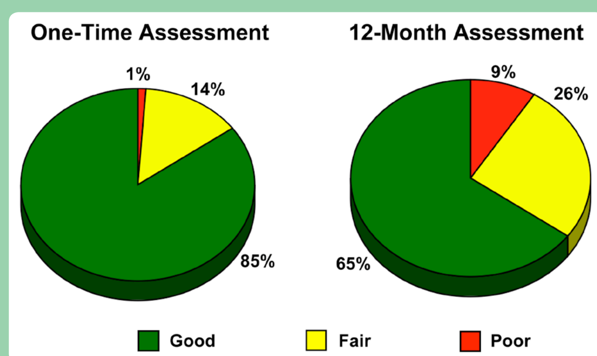

Figure A. Percent of the state's estuarine habitat that codes as good, fair, or poor based on the one-time SCECAP integrated water quality score and the 12-month integrated water quality score.

SCECAP IWQS Versus SCDHEC 305(b) Reporting

For a stricter comparison of the SCECAP IWQS and the SCDHEC 305b reporting, which includes additional parameters not used in the SCECAP IWQS, a different approach was required. Parameters considered in the 305(b) reporting include dissolved oxygen, pH, fecal coliform bacteria, turbidity,

Table B. Percent of open water and tidal creek core sites classified as good, fair, or poor based on 12-month and one-time assessments for each parameter.

		Open Water			Tidal Creek		
Measure	**Assessment**	**Poor**	**Fair**	**Good**	**Poor**	**Fair**	**Good**
IWQS	12-Month	6	23	71	23	37	40
	One-time	0	13	77	3	20	77
Dissolved Oxygen	12-Month	0	3	97	3	23	74
	One-time	3	6	91	0	20	80
pH	12-Month	17	8	75	18	5	77
	One-time	0	15	85	0	11	89
Fecal Coliform	12-Month	10	26	64	7	33	60
	One-time	0	19	81	7	23	70
Total Nitrogen	12-Month	3	10	87	13	0	87
	One-time	0	14	86	7	7	84
Total Phosphorous	12-Month	45	3	52	33	10	57
	One-time	7	16	77	3	50	47
Chlorphyll-*a*	12-Month	6	10	84	30	20	50
	One-time	0	6	94	13	17	70

ammonia, cadmium, chromium, copper, lead, mercury, nickel, and zinc, but the SCECAP IWQS only includes the first three parameters. The 305(b) report provides results on fecal coliform bacteria related to human health issues in a separate use category (recreational use) from the other parameters whose thresholds are set to protect aquatic organisms (aquatic life use). Therefore, the comparison of the SCECAP IWQS and the 305(b) report is limited to only two categories: *good* for both uses, or *other* (i.e., fair or poor for either or both uses). Additionally, the 305b report does not evaluate tidal creeks and open water habitats separately. Therefore, the two habitat types were combined for this comparison.

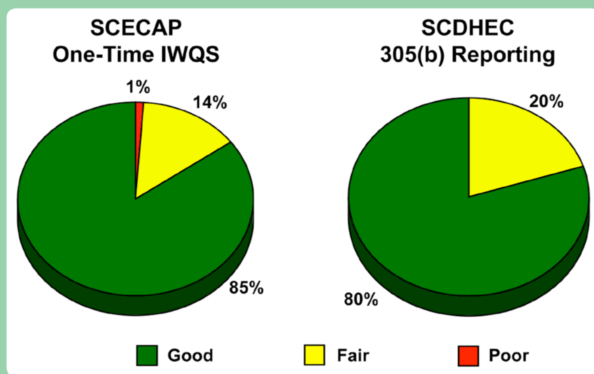

Figure B. Percent of the state's estuarine habitat that codes as good, fair, or poor based on the one-time SCECAP integrated water quality score and the SCDHEC 305(b) reporting methodology.

The SCDHEC 305(b) assessment results are in closer agreement with the one-time SCECAP data than the 12-month SCECAP IWQS despite using a very different set of parameters and employing different thresholds (Figure B). However, given the differences in assessment methods, parameters, and threshold values, this apparent degree of agreement may be coincidental.

In summary, it appears that the one-time assessment of state water quality condition used for SCECAP may not be as sensitive to detecting water quality impairment as a year-round sampling approach. It is important to note that state water quality criteria have not been established for nutrients and chlorophyll-a (3 of the 6 components of the SCECAP IWQS), so the differences may not be of great concern, especially considering that much of the difference is related to exceedances of the SCECAP criteria for phosphorus. Based on the lack of any significant relationship between phosphorus concentrations and chlorophyll-a concentrations, phosphorus may not be appropriate to include in future integrated water quality indices. SCDHEC and SCDNR staff will be reviewing both the SCECAP IWQS thresholds and list of parameters included on a periodic basis.

habitat was considered to have good fecal coliform concentrations, 16% was not likely to be suitable for shellfish harvesting and 6% had coliform concentrations considered to be very poor and not likely to be suitable for primary contact recreation or shellfish harvesting (Figure 3.2.2). The locations of sites that had moderately high to very high fecal coliform counts are provided in Appendix 2.

Even though the mean values of fecal coliform concentrations were much higher in both habitat types compared to the 2001-2002 survey, there was not a substantial change in the percentage of the state's habitat that had undesirable bacterial levels (Figure 3.2.6) The higher fecal coliform counts observed in creek habitats is most likely due to the proximity of these small drainage systems to upland runoff from both human and domestic wastes as well as wildlife sources, combined with the lower dilution capacity of creeks compared to larger water bodies. Greater protection of tidal creek habitats is warranted in areas where upland sources of waste can be identified and controlled.

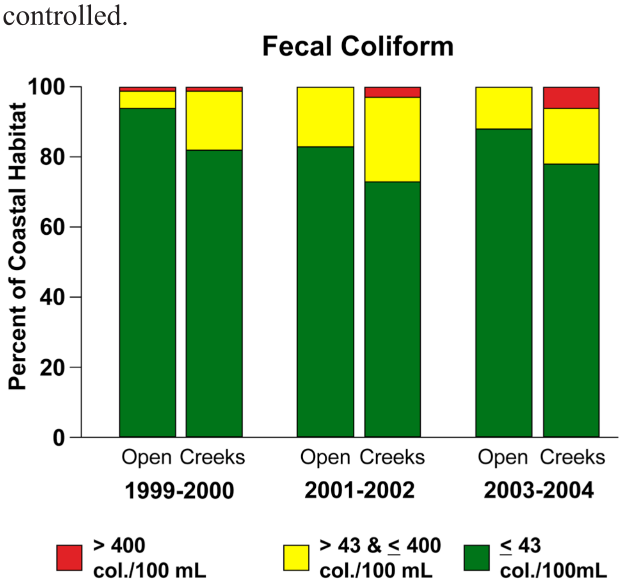

Figure 3.2.6. The percent of the state's coastal habitat representing various fecal coliform concentrations that are considered good (green), fair (yellow) and indicative of possible unsuitability for shellfish harvest, or poor (red) and indicative of possible unsuitability for primary contact recreation and shellfish harvesting during the three survey periods conducted to date.

Turbidity

Measures of water clarity provide an indication of the amount of suspended particulate matter in the water column. Exceptionally high turbidity levels may be harmful to marine life. South Carolina's estuarine waters are naturally turbid compared to many other states. SCDHEC has recently developed a maximum saltwater state standard for turbidity of 25 NTU. This corresponds to the 90th percentile of the SCDHEC saltwater database, which was obtained primarily from the larger estuarine water bodies. The 75th percentile of turbidity values obtained from SCECAP sampling was 15 NTU. Therefore for SCECAP, turbidity values ≤ 15 NTU are considered to be good, values > 15 NTU and ≤ 25 NTU are considered to be fair, and values > 25 NTU are considered to be poor because they contravene the SCDHEC standard.

While the SCECAP program recognizes the need to have turbidity standards, the standards are not incorporated into our overall water quality index at this time. Mean turbidities measured in the 2003-2004 survey by this program were 21.9 NTU in tidal creeks and 12.4 NTU in open water habitat (data online), which are very similar to the means noted in previous survey periods (Van Dolah *et al.,* 2002a, 2004a). As observed in the previous surveys, the difference between habitats was statistically significant ($p < 0.001$). Based on the single measure of turbidity taken at each station, approximately 29% of the tidal creek habitat exceeded the State standard, whereas only 7% of the open water habitat exceeded the standard (data online). Turbidity levels in tidal creeks may be naturally higher due to the shallow depths of these systems (i.e. surface samples are often within 1-2 m of the bottom) combined with re-suspension of the bottom sediments due to tidal currents. Because of the high turbidity levels observed in tidal creek habitats over the six years sampled by SCECAP (Box 3.2.1), this program has elected to not include this parameter in the integrated water quality index.

Integrated Assessment of Water Quality

SCECAP has developed an integrated measure of water quality using multiple parameters combined into a single index value (Van Dolah *et al*., 2004a). Six parameters are included in the index: dissolved oxygen (DO), pH, total nitrogen (TN), total phosphorus (TP), chlorophyll-*a* concentrations, and fecal coliform bacteria. DO and pH can indicate whether waters are stressful for many marine species. TN and TPs provide measures of nutrient concentrations, and combined with chlorophyll-*a* concentrations, these three parameters provide evidence of whether nutrient enrichment (eutrophication) may be occurring in South Carolina's estuaries. Fecal coliform concentrations provide an indication of the suitability of the water for shellfish harvesting and primary contact recreation.

Computation of the integrated water quality index is described by Van Dolah *et al*. (2004a; available online). For SCECAP, integrated scores > 4 represent good water quality conditions, scores > 3 but ≤ 4 represent fair water quality conditions, and scores ≤ 3 represent relatively poor water quality conditions, and scores .

Results of the 2003-2004 survey indicated that approximately 87% of the state's open water habitat had good water quality overall, 13% had fair quality, and none had poor water quality (Figure 3.2.2). In contrast, 75% of the state's creek habitat during this survey period had good, 22% had fair, and 3% had poor water quality. This was very similar to conditions observed in 2001-2002, which represented a drought period compared to the current survey. The creek sites with poor overall water quality were located in Rock Creek near the Ashepoo River and a tidal creek near Middleton Gardens in the Ashley River (Appendix 2).

As noted in the previous surveys (Van Dolah *et al*., 2002a, 2004a), the higher percentage of fair and poor water quality conditions in creeks indicates that these habitats are often naturally more stressful

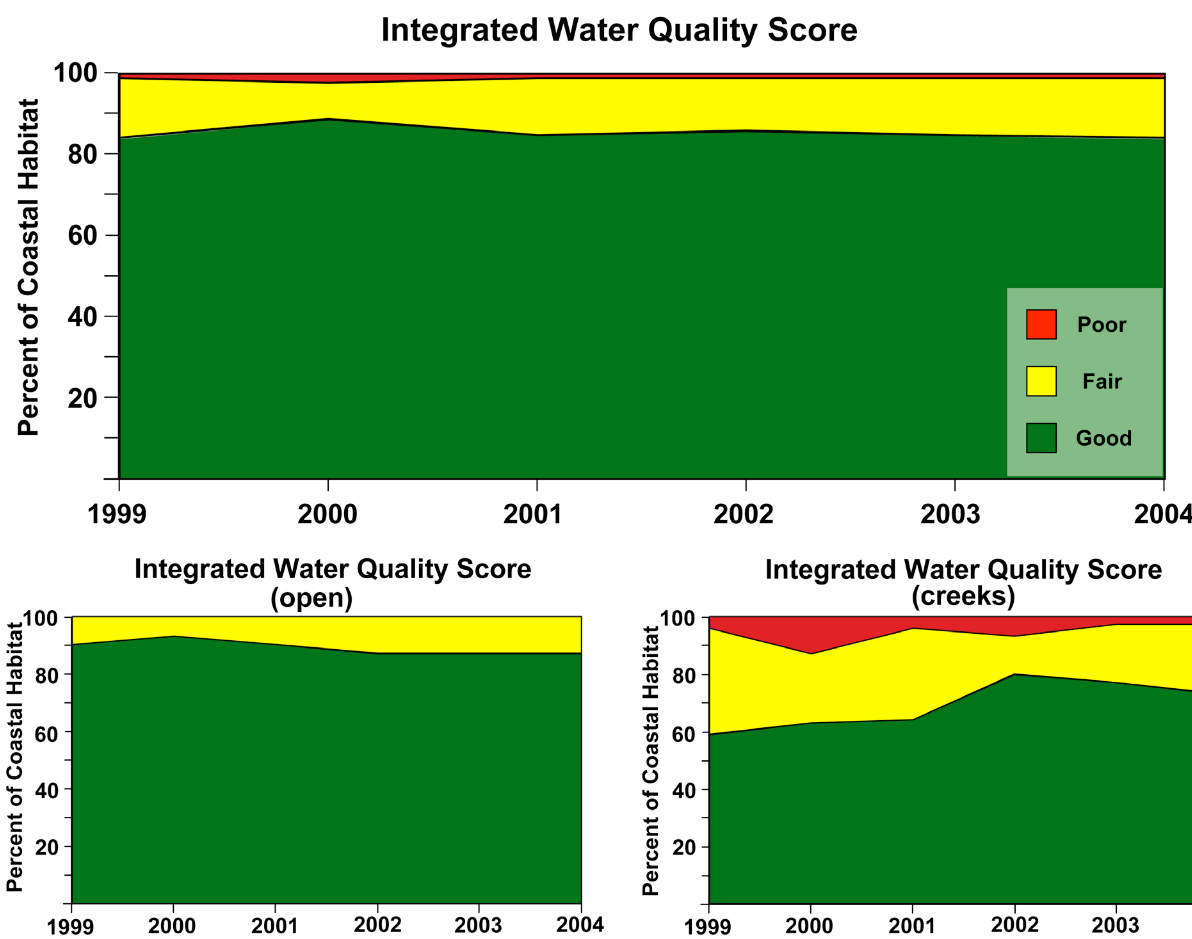

Figure 3.2.7. Proportion of the South Carolina's estuarine habitat that ranks as good (green), fair (yellow) or poor (red) using the integrated water quality score compared on an annual basis when tidal creek and open water habitats are combined and for tidal creek and open water habitats considered separately.

environments, especially since many of these sites were in relatively pristine locations. The higher percentage of creek habitat with fair or poor conditions may also reflect, in part, the relatively greater effect of anthropogenic runoff into these smaller water bodies due to their proximity to upland sources and their lower dilution capacity.

Comparison of the state's overall water quality condition on an annual basis indicated very little change over the six years sampled by SCECAP to date (Figure 3.2.7). This is surprising since the state's estuarine habitat was altered considerably by increased rainfall in 2003 and 2004 based on the changes in the proportion of the state represented by the various salinity zones (Figure 3.2.1). For all years, about 80% or more of the state's estuarine waters rank as good in quality using the SCECAP criteria, and generally less than 5% of the estuarine waters ranked as poor in quality. We anticipated that the increased rainfall experienced during 2003-2004 might have an impact on the state's overall estuarine water quality, but the resulting data did not confirm this. Although some of the component parameters did show evidence of considerable change, the actual concentrations observed among the various sites sampled in a given year, combined with the mitigating effects of those parameters that did not show much change, are the probable reasons for a lack in major changes in the integrated water quality index.

3.3 Sediment Quality

Sediment Composition

The composition of marine sediments can affect the structure of benthic communities, the exchange rates of gases and nutrients between the water column and seafloor, and the bioavailability of nutrients and contaminants to resident fauna (Gray, 1974; Graf, 1992). In general, muddier sediments (those with more silt and clay) tend to host a different set of species, reduce the movement of gasses and nutrients, and retain more contaminants than sandier sediments.

During the 2003-2004 monitoring period, sediments in open water habitats were on average 19.6% silt/clay while sediments in tidal creek habitats were 30.4% silt/clay, a difference that was significant ($p = 0.013$). Within each habitat type, the percent silt/clay was highly variable, with open water stations varying from 0.7-94.7% and tidal creek stations varying from 2.0-97.8%. The sediments at one open water station (2.0%) and four tidal creek stations (7.0%) had greater than 80% silt/clay (Figure 3.3.1). These values are similar to previous study periods (Van Dolah *et al.,* 2002a, 2004a).

Sediment Total Organic Carbon

Total organic carbon (TOC) represents a measure of the amount of organic material present in sediments. At very low TOC levels, little food is available for consumers resulting in a low biomass community; at very high TOC levels, enhanced sediment respiration rates lead to oxygen depletion and accumulation of potentially toxic reduced chemicals. Hyland *et al*. (2000) found that TOC levels below 0.5 mg/g (0.05%) and above 30 mg/g (3.0%) were related to decreased benthic abundance and biomass.

The TOC content of open water sediments averaged 0.8% while tidal creek habitats averaged 1.2%, a difference that was significant ($p = 0.048$). The TOC of open water habitats varied from 0.03% to 5.5% and that of tidal creeks varied from 0.05% to 5.5%. Based on the criteria in Hyland *et al.* (2000), the sediments were impaired with respect to TOC at 20% of open water habitats (14% too low, 6% too high) and 15% of tidal creek habitats (3% too low, 12% too high; Figure 3.3.1). These values are similar to previous surveys (Van Dolah *et al.,* 2002a, 2004a). The tendency of open water habitats to be characterized by lower TOC levels than tidal creek habitats likely reflects their greater distance from terrestrial sources of organic material.

Porewater Ammonia

Total ammonious nitrogen (TAN) provides a measure of the concentration of ammonia, a highly reduced and potentially toxic form of nitrogen, in marine sediments. Sources of ammonia include terrestrial runoff, atmospheric deposition and bacterial activity (nitrate reduction and ammonification), many of which are increasingly impacted by human activities, resulting in greater nitrogen loads in coastal environments (Driscoll *et al.,* 2003).

The median porewater ammonia concentration was 1.9 mg/L in open water habitats and 2.1 mg/L